Future aerospace vehicles can be enabled by NASA technology. Pictured clockwise from the top: advanced general aviation aircraft, advanced rotorcraft, a tiltrotor aircraft used as an emergency medical transport, a 300-passenger supersonic transport, a 600-passenger subsonic transport (a Blended Wing Body concept), and a reusable launch vehicle for transporting cargo to orbit. Technology will also fundamentally change the way pilots, ground controllers, and schedulers communicate, to help enable highly-efficient and accident-free airspace and terminal operations.

Goal One: Revolutionize Aviation

NASA's goal is to enable the safe, environmentally friendly expansion of aviation.

Expanding the aviation system of the future to meet demands for growth will mean providing a more distributed, flexible, and adaptable network of airways. This growth must take place within the physical and environmental constraints of today's system, while meeting the evolving needs of air travel. The system of the future will continue to be international in scope, requiring close coordination across a global network. Advanced vehicles will operate in this new infrastructure, with better performance and new capabilities, such as "morphing" wings that optimize their shape for take-off, flight, and landing. Advanced information and sensor technologies will make air travel safer and more efficient. Air transportation will be easily accessible from urban, suburban, or rural communities and affordable for all citizens. Airplanes will be cleaner, quieter, and faster. NASA aims to revolutionize aviation by delivering the long-term, high-payoff aerospace technologies, materials, and operations research needed for enabling these new vehicle and system characteristics and capabilities.

Objective 1: Increase Safety
Make a safe air transportation system even safer.

Reduce the aviation fatal accident rate by a factor of 5 within 10 years and by a factor of 10 within 25 years.

Although the commercial aviation accident rate is very low, that rate has remained stubbornly constant for the past two decades. Even with the current low accident rate, the anticipated growth in commercial aviation would mean an accident frequency approaching a major accident every week. This could result in a perception that air travel has become unsafe, which could inhibit the full growth potential of the air travel market. This national objective is intended to reduce the accident rate such that, even with traffic growth and an aging aircraft fleet, the frequency of future accidents will be reduced as compared with the baseline period of 1990 to 1996.

NASA's strategy for achieving this objective is to pursue three major technology thrusts:

- System Monitoring and Modeling—Develop technologies for using the vast amounts of data available within the aviation system to identify, understand, and correct aviation system problems before they lead to accidents.
- Accident Prevention—Identify interventions and develop technologies to eliminate the types of accidents that can be categorized as "recurring."
- Accident Mitigation—Develop technologies to reduce the risk of injury in the unlikely event of an accident.

Metrics for quantifying progress in each of the thrust areas include accident rate, fatal accident rate, number of fatalities, and number of injuries.

Outcomes
Successful research and development efforts that lead to improved vehicles and operational practices would result in:

- Elimination of major categories of recurring accidents.
- Early warning and prevention of hidden and potential safety issues.
- Reduced risk of injury to passengers and crew in the unlikely event of an accident.

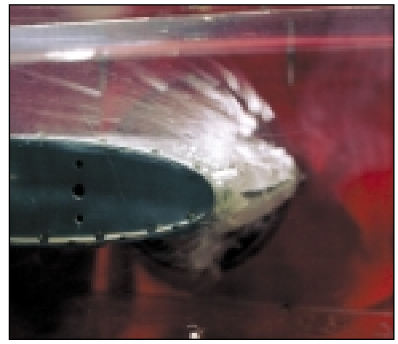
Synthetic vision systems being developed at Langley Research Center, combine accurate geo-positioning, digital terrain databases, and digital data links to portray an accurate representation of the terrain, air traffic, runway hazards, ground structures, and other equipment in low-visibility conditions. Such systems will help eliminate hazardous runway incursions and controlled-flight-into-terrain (CFIT) accidents, as well as improving all-weather operational efficiency.

Objective 1: Increase Safety

Key Strategy and Partnership Issues

Reducing the accident rate requires technologies and strategies that target recurring types of accidents and precursor events. Developing these technologies and strategies entails continually improving in our understanding of the root causes of accidents. To do so will require full, proactive access to and use of all the data available in the aviation system.

Success will require the formation of alliances with the Federal Aviation Administration (FAA) and others across the aviation community. We will also enhance our partnership with DoD to address common problems in aircraft safety, such as aging systems. Key aspects of these alliances include developing high confidence methods for determining the effectiveness of new tools and technologies; accelerating the insertion of safety technologies into existing and new aircraft through industry and FAA partnerships; and introducing the technology into the commercial aviation system through specific technology partnerships.



Officially known as the Electro-Expulsive Separation System, the "ice zapper" could greatly increase aircraft flight safety. It uses one-thousandth the power and is one-tenth the weight of typical electrothermal ice removal systems and can remove layers of ice as thin as frost or as thick as an inch of glaze. This high-speed photo captures ice as it is zapped from a wing surface.

Objective 2: Reduce Emissions

Protect local air quality and our global climate.

Reduce NO_x emissions of future aircraft by 70 percent within 10 years, and by 80 percent within 25 years (using the 1996 ICAO Standard for NO_x as the baseline). Reduce CO_2 emissions of future aircraft by 25 percent and by 50 percent in the same timeframes (using 1997 subsonic aircraft technology as the baseline).

The International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection is addressing worldwide concerns about local air quality and climate change. The 1999 report "Aviation and the Global Atmosphere," issued by the Intergovernmental Panel on Climate Change (IPCC), projects that aviation's emission of carbon dioxide (CO_2) in the year 2050 will be up to 10 times greater than in 1992. Furthermore, in response to stringent ozone and particulate matter standards under the U.S Clean Air Act, local authorities and environmental groups are demanding action from Federal agencies and air carriers. They want to reduce emissions of nitrogen oxide (NO_x), which is suspected of contributing to toxic ozone production, as well as other pollutants. In the long run, technology is superior to other actions such as regulation, which could constrain aviation growth.

Lean-burning (low fuel-to-air ratio) combustors can greatly reduce engine emissions, but they have an increased susceptibility to thermo-acoustic instabilities. These high-pressure oscillations, much like sound waves, can fatigue combustor components and even the downstream turbine blades, decreasing their safe operating life. With active combustion control, being developed at Glenn Research Center, pressure oscillations can be put into the system by pulsing the fuel (shown above), canceling out the oscillations from the instabilities. Thus, the engine can have lower pollutant emissions and a longer life. Shown are the pulsating fuel modulations used to suppress combustion instabilities.

Objective 2: Reduce Emissions

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Airframe Weight and Drag Reduction**—Develop airframe technologies that reduce fuel consumption and therefore reduce CO_2 and NO_x emissions.
- **Propulsion Optimization**—Develop advanced engine system technologies to reduce emissions such as NO_x that have an impact on local air quality and those such as CO_2 that affect the global climate.
- **Operation Optimization**—Develop more efficient operations at and around airports, in order to reduce aviation fuel burn and therefore reduce emissions.
- **Alternative Vehicle Concepts**—Develop advanced concepts for propulsion systems, airframe structures, and fuels that dramatically reduce or completely eliminate emissions from civil aviation aircraft.

Metrics for these thrusts include the reductions in the percentage of Landing/Take-Off (LTO) NO_x (relative to those in the 1996 ICAO LTO NO_x standard), total NO_x (g NO_x/asm), and total fuel burn/CO_2 (kg CO_2/asm).

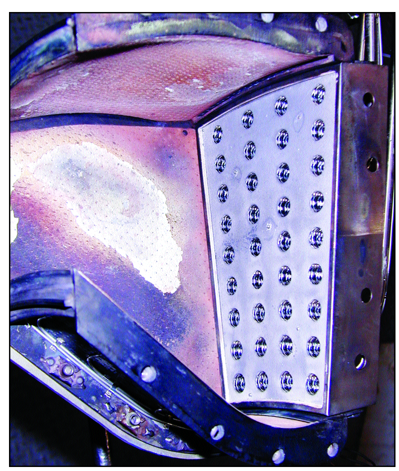
Outcomes

Successful research and development efforts that lead to improved vehicles and operational practices would result in:

- Significant or total elimination of aircraft emissions as a source of climate change.
- Minimized impact of emissions on local air quality.
- Elimination of unnecessary aviation emissions due to operational procedures.
- Non-traditional, environmentally compatible modes of propulsion for civil aviation.

Key Strategy and Partnership Issues

Aviation has continually adopted the best technologies with each succeeding generation of aircraft. As a result, the aviation industry is not able to apply "quick fixes" in response to demands for reduced emissions. In implementing emissions reduction technologies, a careful balance must be maintained to ensure success. The new technologies must be consistent and compatible with affordable air travel, airspace operations, and noise reduction technologies, and must not have a negative impact on safety. Likewise, improved aircraft operations to reduce emissions must be compatible with capacity improvements. NASA will work with DoD to leverage technologies that contribute to aircraft efficiency; and will also work with industry, the FAA, the Environmental Protection Agency (EPA), and international organizations to ensure that technology development and adoption are viable alternatives to regulation.



The next generation of revolutionary combustors will employ multipoint arrays of lean-burning combustion zones to enable reduction of NO_x emissions to extremely low levels. This multipoint array of lean direct injectors is shown integrated into a sector combustor rig.

Objective 3: Reduce Noise

Reduce aircraft noise to benefit airport neighbors, the aviation industry, and travelers.

Reduce the perceived[6] noise levels of future aircraft by a factor of 2 (10 decibels) within 10 years and by a factor of 4 (20 decibels) within 25 years, using 1997 subsonic aircraft technology as the baseline.

Aircraft noise has diminished dramatically in the last 30 years, enabling a tremendous net reduction in the number of people affected by aircraft noise. However, the impact of noise from aircraft operations continues to constrain the air transportation system through curfews, noise budgets, and slot restrictions; and the number of airports affected by local noise restrictions has grown significantly worldwide. Public expectation is clearly for reduced noise impact and, in the absence of appropriate technology, that impact is handled through constraints, such as inhibiting expansion or construction of new facilities. Increasingly stringent standards governing aircraft noise have mandated a phase-out of Stage 2 airplanes by the year 2000. Stage 3 is already in effect and Stage 4 is looming on the horizon. The long-term 20-decibel objective for noise reduction will, in most cases, when implemented throughout the fleet, contain objectionable aircraft noise within the airport boundaries (55 Day Night Level contour), freeing the system of most noise restraints.

The noise reduction challenges are being addressed through three strategic thrusts. Pursuit of these thrusts may yield low-noise aircraft that reduce noise in areas near airports and eliminate operational restrictions by keeping aircraft noise within the airport boundaries.

Computational codes pioneered by Langley and Glenn Research Centers have enabled the design of swept and leaned fan stators that reduce fan noise by 3dB without sacrificing engine performance or efficiency.

Objective 3: Reduce Noise

- **Propulsion System Source Noise Reduction**—Develop technologies to reduce engine noise at the source.
- **Aircraft System Source Noise Reduction**—Develop technologies to diminish airframe-related noise.
- **Operational Noise Reduction**—Develop advanced aircraft operating procedures, including steeper glide-slopes and precision, wind-compensated flight paths.

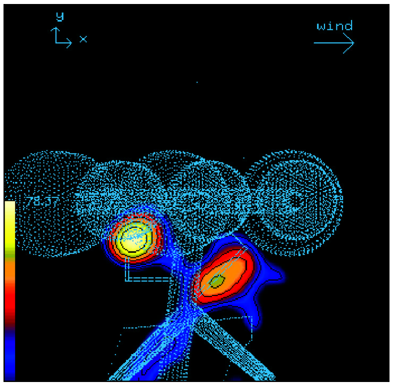
The metric related to the noise reduction thrusts is Effective Perceived Noise (EPNdB).

Outcomes

Successful research and development efforts that lead to new vehicles and operational practices would result in:
- Quieter airframes and propulsion systems that confine noise impact to the airport boundaries.
- Air traffic management operations that minimize the impact of noise.

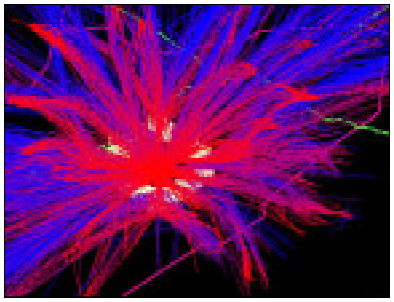
Key Strategy and Partnership Issues

The key issue in this objective is to shrink the noise "footprints" from around airports to within airport boundaries. Achieving this creates a "win-win" situation for local communities and aviation, by reducing the impact of airport noise on communities and at the same time eliminating operational restrictions based on noise. The ability to operate both night and day will create new travel choices for the public, greater capacity for delivery of freight, and economic benefits that can be passed on to the consumer in terms of lower prices for tickets and consumer goods. NASA will work with the FAA, EPA, and industry to accelerate development and adoption of technologies that create a viable alternative to regulation. The DoD also needs to be a good neighbor to communities near military airbases, and will partner with NASA on noise reduction technologies.



A computerized image of wind noise around a landing gear model displays the sounds that occur during takeoffs and landings. Pictures of the sounds are similar to the "false color" of infrared film images of heat. Such computer models will allow for the redesign of landing gear for minimum noise.

[6] *The word "perceived" is key to the intended interpretation of the Enterprise noise reduction goal. In subjective acoustics, noise that is reduced by 10db is perceived as being "half" as loud; therefore, the stated interpretation of the goal.*



Tools for air traffic management show, in this unique image, an entire 24-hour pattern for all incoming (red) and outgoing (blue) aircraft at Dallas-Fort Worth International Airport. This type of computer modeling and visualization capability is essential to understanding and solving airport capacity and delay problems.

Objective 4: Increase Capacity[7]

Enable the movement of more air passengers with fewer delays.

Double the capacity of the aviation system within 10 years and triple it within 25 years, based on 1997 levels.

NASA's focus is on the capacity to move significantly more aircraft through the aviation system safely with less delay.

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

- **Infrastructure and Operation Optimization**—Optimize use of the current infrastructure without adding new airports or new runways by developing Air Traffic Management (ATM) technologies that increase the efficiency and capacity of the NAS.
- **Alternative Vehicle Concepts**—Develop new civil aviation vehicle concepts that are designed to use segments of the NAS not suited for traditional commercial aircraft, such as short runways and vertical take-off and landing pads.
- **Alternative Infrastructure Concepts**—Develop entirely new concepts and systems, such as fully automated towers and airports, that would increase the use and capacity of the Nation's 5000 public-use airports.

[7] The factors for capacity are based on predicted demand growth in revenue passenger miles (RPMs). The capacity and delay baseline reflects the proportion of good and adverse weather conditions that typically occur on an annual basis.

Objective 4: Increase Capacity

Metrics for these thrusts include annual operations, revenue passenger miles (RPM), and average delay.

Outcomes

Successful research and development efforts to improve the NAS would result in:

- Better use of the existing NAS without compromising safety; for example, safe all-weather operation.
- Real-time, distributed, “intelligent,” and automated monitoring of the entire aviation system, and safety and operational advisories.
- More productive use of all the Nation’s airports, by including short-runway and runway-independent aircraft in the NAS.
- High productivity, weather-tolerant vehicle systems capable of intermodal operations.
- Increased capacity, significantly beyond gains made by optimizing the current system.

Key Strategy and Partnership Issues

Alternative vehicle concepts and infrastructure concepts must be developed interdependently to ensure that they can operate together successfully as well as increase the capacity of the NAS. The thrusts must be worked in close partnership with the FAA, U.S. air carriers, manufacturers, and operators. The FAA’s Free Flight Program to transition to a modernized NAS over the next 5 to 10 years provides a major opportunity to integrate NASA technologies. Research on concepts and technologies to increase airspace system throughput will be a priority for the foreseeable future.

FutureFlight Central, an award-winning full-scale air traffic control tower simulator at Ames Research Center, provides realistic airport conditions and configurations. It will allow researchers to look at the feasibility, safety, reliability and cost benefits of technologies before they are incorporated into airports, and can assist in the design of new airport facilities or proposed changes for existing airports. Deployed on the seamless out-the-window field-of-view is San Francisco International Airport. Shown are research staff Bob McMahon, Jim McClenahen, Boris Rabin, and Cedric Walker.

FJX-2 engine technology, developed in partnership with NASA by Williams International and its industry team, is at the heart of the new Eclipse 500 six-passenger jet (first deliveries are expected in 2003). The EJ22 commercial engines on this aircraft are based on FJX-2 engines, which produce 700 pounds of thrust, yet weigh only 85 pounds, nearly twice the thrust-to-weight ratio previously available.

Objective 5: Increase Mobility
Enable people to travel faster and farther, anywhere, anytime.

Reduce inter-city door-to-door transportation time by half in 10 years and by two-thirds in 25 years, and reduce long-haul transcontinental travel time by half within 25 years.

Improving the mobility of U.S. citizens by reducing travel time for both short and long journeys requires a wide range of innovations and improvements. NASA is working on methods to integrate small aircraft and all public use landing facilities into the national air transportation system, to increase significantly the access to the air transportation network, reducing travel times into and out of every community. This will require improvements both to aircraft and to the network of small airports. For long journeys, affordable supersonic travel will be essential, but the technological challenges are significant. NASA is working to resolve specific technology problems such as sonic booms, engine noise, and emissions.

NASA will also assess new vehicle design concepts, develop advanced mobility concepts such as the tiltrotor, and fully integrate them within the total aviation system. All these will contribute to reductions in travel time.

NASA's strategy for achieving this objective is to pursue the following technology thrusts:

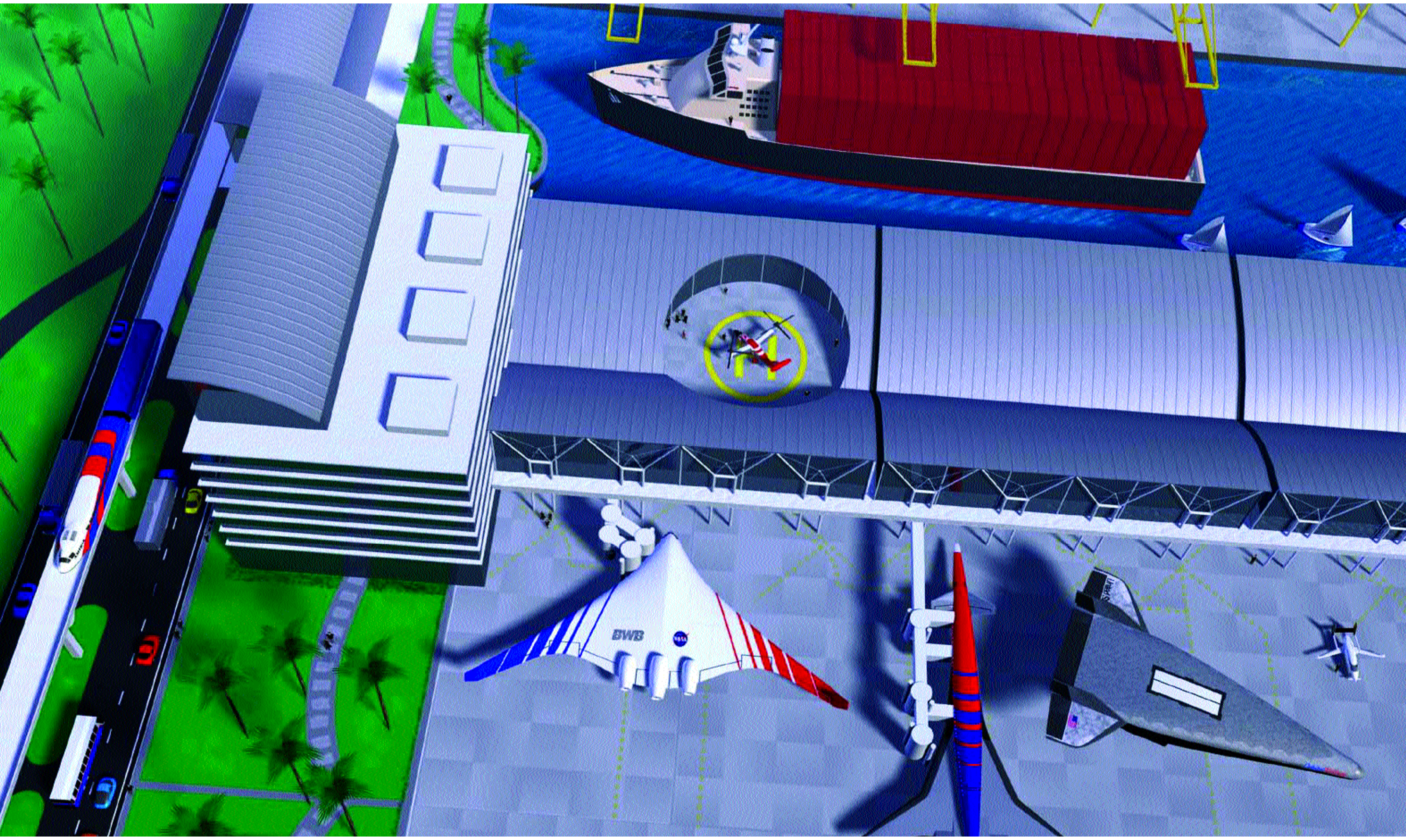
- **Small Aircraft Transportation**—This thrust will focus on developing vehicle, communication, and information technologies to allow small aircraft to operate easily and affordably at small airports in most weather conditions.
- **Supersonic Transportation**—Develop technologies critical to the economic viability of supersonic transport, such as propulsion concepts that meet stringent noise and emissions criteria.
- **Advanced Mobility Concepts and Technology**—Investigate non-traditional vehicles and operations concepts to take advantage of operational airspace that is currently underused.

Metrics associated with the mobility thrusts include inter-city access and trip efficiency, and long-haul trip times.

Outcomes
Successful research and development efforts to improve the NAS would result in:

- A Small Aircraft Transportation System (SATS) featuring affordable, all-weather use of the Nation's public-use landing facilities.
- An economically competitive supersonic transportation capability that is as safe and environmentally compatible as subsonic air travel.
- New aircraft configurations for more efficient use of the airspace system.

Objective 5: Increase Mobility



Information technology will help revolutionize future aerospace vehicles as well as the transportation system and its operation. With multiple interfaces shared information, and infrastructure elements, the transportation system will become more flexible and intermodal in nature. The foundation of communication and information will enable a future system that can economically move anyone and anything anywhere, anytime, on time. Shown is a concept where advanced vehicles for air, surface, rail, and waterway transportation are converging at a station designed for the efficient transfer of people and goods.

Key Strategy and Partnership Issues

Better small aircraft transportation will require systems innovations allowing small aircraft to become an integral part of the commercial air transportation system. The strategy is to expand the framework of the public-private sector partnership, which is being used in current efforts to advance general aviation. This partnership can accelerate the development, integration, and demonstration of technologies required to prove the concept that a small aircraft system can coexist and flourish with the commercial air transportation system, and can augment the system as well.

For supersonic transportation, NASA will focus its research on basic technologies to meet stringent design criteria. A significant effort will be made to explore a broad set of technology options. The program will also examine research in space transportation technologies for opportunities to leverage existing work. A key strategy will again include government-industry partnerships. Early partnerships to identify, develop, and implement advanced aircraft design and performance concepts will help the industry team later in developing a commercial aircraft.